A FULLY AUTOMATED EGG FOR TELEMETERING ADULT ATTENTIVENESS AND INCUBATION TEMPERATURES*

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ABSTRACT. The construction and operation of a temperature and light telemetering egg are described. The egg was used to gather incubation temperature and nest attendance data at two Golden Eagle (*Aquila chrysaetos*) eyries. The system is low cost, has the advantages of long life and low maintenance, and is operable with a minimum of disturbance at the nest.

Incubation temperatures have been monitored by thermistors and thermocouples placed in the nest (Baldwin and Kendeigh 1927, Norton 1972), inside real eggs (Snelling 1972), and inside dummy eggs (Holstein 1942, Norton 1972). All of the above systems have disadvantages. Exposed wires interfere with egg turning activities of parent birds. Sensors in the nest itself measure ambient temperature rather than egg temperature.

Photoresistors placed in the nest floor can give an index of parental attendance (Weeden 1966), but errors are introduced when nest litter, eggs or young birds cover the sensor.

A better approach to recording both temperature and adult attendance is to install light and temperature sensors inside the egg. Small temperature recorders have been placed inside eggs (Lind 1961, Drent 1967), but short-term operation life (up to 12 hours) necessitated frequent visits to the nest and disturbance to the parents. This disadvantage was, in part, overcome by using a radio signal to relay data to nearby recording equipment (Eklund and Charlton 1959). Their system had an operating life of 100 hours so disturbances were less frequent but not eliminated.

Recent advances in electronic components have made possible the construction of an inexpensive and accurate monitoring system capable of operating during an entire nesting season. The system presented in this report relays both

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light (adult attendance) and incubation temperatures from a dummy egg to a loop antenna surrounding the nest cup and below the surface of the nest. A lead from the receiving antenna to receiving and recording equipment makes it possible to check equipment and replace batteries without disturbing the adults.

The need for a system that could provide a maximum amount of data on parental attentiveness and incubation temperatures (both peripheral and central) was strongly suggested at both the 1971 (Olendorff 1972) and 1972 conferences on captive breeding of raptors.

Egg Construction

The telemetering egg, designed in 1972, contains switch and timing circuits, sensors monitoring core temperature, shell temperature, and ambient light, and a blocking oscillator pulse transmitter. Schematic diagrams of the circuitry of the egg and pulse rate convertor have been published elsewhere (Varney and Ellis 1974).

The system has the advantages of low power consumption. The drain by transmitter and logic circuit is 30 μA resulting in a predicted life of two years for a 23 gram, 500 mAH mercury battery.

For eagle-egg application .size was not a problem, so four integrated circuitry packages of the inexpensive epoxy type were employed. For smaller eggs, smaller packages can be obtained at higher costs. With readily available components it is possible to fit the circuit into a 15 cm^3 egg and obtain a 60-day operating life. Typical component cost is $25 for an eagle egg and $48 for smaller eggs. If even smaller eggs are desired, component costs rise sharply, but construction is possible especially if only a one- or two-channel system is required.

Sensor components can be temperature-calibrated prior to assembly or the completed unit can be calibrated in a constant-temperature water bath. By either method an accuracy of $\pm$ 0.2 degrees Centigrade is achieved.

For studying the Golden Eagle (*Aquila chrysaetos*), we used an oversized Domestic Chicken (*Gallus gallus*) egg. The egg fell within the length-width dimention ranges reported by Bent (1937:299) for the Golden Eagle. The egg was sawed open, drained, and coated within by a thin layer of dental acrylic. The electronic guts were inserted, and the egg was filled with paraffin, which is thermally much like avian albumins. The end cap was then attached with acrylic so that an air space lay between the photoresistor and the cap. In 1972 the shell was spotted with water colors which subsequently eroded away, so in 1973 the egg was camouflaged with spray enamel.

The assembled egg was thermally much like a natural egg. Its density and specific heat were 1.10 g/ml and 0.63 cal/g deg C as compared with 1.09 g/ml and 0.77 cal/g deg C for comparable parameters of a natural egg (Romanoff and Romanoff 1949:105, 376). The instrumented egg was resultantly heated and cooled about 18% faster than a natural egg.

Receiving and Recording Equipment

The low power consumption is, in part, reflected in rapid attenuation of the signal with distance. The egg should be within two meters of a receiving antenna. The antenna, hidden in the nest surface, consisted of a 20-turn coil of number 24 AWG wire. Our antenna coil was approximately 50 cm in diameter, but smaller coils can be used where desired. An unshielded, two-conductor, cable lead (up to 40 m long) can be made between the loop antenna and the receiver. This lead connects to a standard broadcast-band receiver. Any small, battery-operated receiver with an earphone jack is suitable. The signal is converted to suitable recording form by a pulse-rate converter.

The pulse rate was displayed and recorded on a 1 mA Rustrak Model 288 chart recorder. At one inch per hour, the Rustrak can collect 25 days of continuous data on a 50-foot roll of chart paper.

A lead-acid automobile battery will operate the receiving and recording system for approximately two months. A total of 40 mA are required for receiver, recorder, and pulse rate converter.

The receiver was tuned on a quiet spot, free from night-time long-distance reception, at a low volume. Too high a volume setting will cause false triggering on background noise.

Approximate receiving system costs include the receiver ($8), pulse rate converter components ($15), and chart recorder ($140).

Installation and Field Performance

In 1972 and 1973 installations were made at one Golden Eagle eyrie each year. The recording equipment was positioned prior to flushing the incubating adult. In 1972 the time between flushing and completion of installation was 37 minutes. In 1973 only about 25 minutes were required. The recording equipment was placed out of sight of the nest at a distance of 30 m. Weekly equipment checks were possible without disturbing or even alerting the incubating adult.

In 1972 the last half of the incubation period was recorded. In 1973 the system was installed four days after laying of the second egg.

A five-hour segment of data is shown as Figure 1. The data from each channel appears as a dotted line, each segment of which represents a 32-second sampling interval for each sensor. "Random" dots between channels appear when the recorder striker-bar operates during the transition between channels. Channels are easily identified by their behavior.

Although it was not the purpose of this paper to present data gathered by the system, I include here a few values from 1972 which illustrate the ranges of the data. The core temperature high was 38 C (100.4 F). The core temperature low was 11 C (51.8 F). High and low peripheral temperatures were respectively 40 C (104.0 F) and 11 C. The greatest duration of adult absence was nine hours (recorded on approximately the 18th day of incubation). The range between extremes in temperature was 27 C (49 F).

Discussion

The telemetering egg system, described above, has been a useful device for

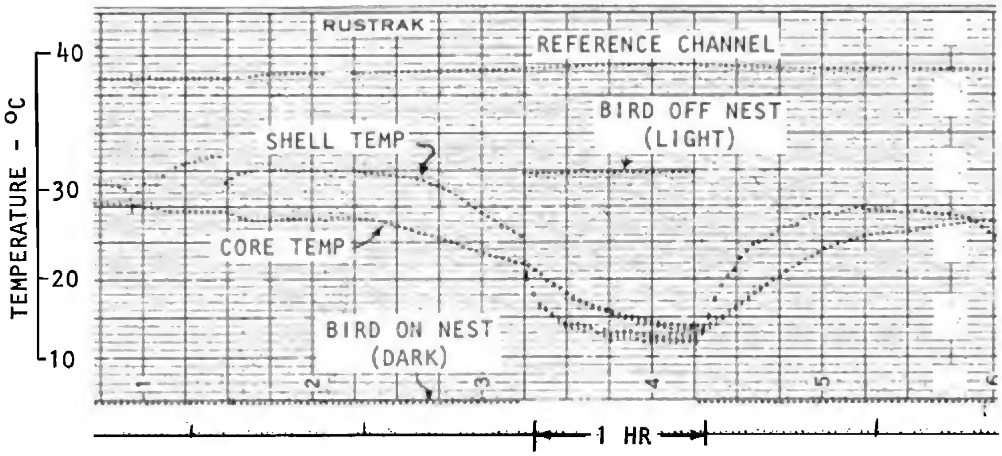

Figure 1. A five-hour data sample. The dotted lines are the recorded data from each of four channels. The upper line, which is consistently just below 40 C, is a reference channel which allows calibration of specific values on the other channels. The light channel was off until hour three (as indicated by the dotted line at the bottom of the chart) after which it jumped to full scale reading (0.6 mA) for about one hour. During the light-on time the adult is not incubating. The shell and core temperature channels are distinguished by their behavior. Shell temperature drops off more rapidly and rises more rapidly when the adult ends and begins incubation, respectively.

obtaining incubation temperatures and behavioral data with a minimum of disturbance to the adults. The system is reasonably simple to construct and operate (even without extensive electronic experience or equipment). The advantages of low maintenance, high accuracy, moderate cost, and multi-channel monitoring are all combined.

The egg circuitry can also be modified for various study objectives. Egg turning rates and additional temperature channels can be included (especially in larger eggs).

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Literature Cited

Baldwin, S. P., and S. C. Kendeigh. 1927. Attentiveness and inattentiveness in the nesting behavior of the House Wren. *Auk* 44(2):206-216.

Bent, A. C. 1937. Life Histories of North American Birds of Prey, Part 1. *U. S. Nat. Mus. Bull.* 169. Reprinted 1961. New York: Dover Publ. 409 pp.

Drent, R. H. 1967. Functional aspects of incubation in the Herring Gull (*Larus argentatus*). Pp. 1-132. *In* Baerends, G. P., and R. H. Drent (eds.) 1970. The Herring Gull and its egg. *Behaviour,* Suppl. 17. Leiden: E. F. Brill. 312 pp.

Eklund, C. R., and F. E. Charlton. 1959. Measuring the temperature of incubating penguin eggs. *Amer. Sci.* 47(1):80-86.

Holstein, V. 1942. Duehøgen, *Astur gentilis dubius* (Sparrman). Biolog. Studier over Danske Rovfugle. I (Copenhagen).

Lind, H. 1961. Studies on the behavior of the Black-tailed Godwit (*Limosa limosa* L.). *Medd. fra Naturfrednigsrådets reservatudvalg* 66:1-157.

Norton, D. W. 1972. Incubation schedules of four species of calidridine sandpipers at Barrow, Alaska. *Condor* 74(2):164-176.

Olendorff, R. R. (ed.). 1972. Special conference on captivity breeding of raptors–a report. Part B. Incubation, Natural and Artificial. *Raptor Res.* 6 (Suppl. B): B7-B35.

Romanoff, A. L., and A. J. Romanoff. 1949. *The Avian Egg.* New York: John Wiley & Sons. 918 pp.

Snelling, J. C. 1972. Artificial incubation of Sparrow Hawk eggs. *J. Wildlife Manage.* 36(4):1299-1304.

Varney, J. R., and D. H. Ellis. 1974. Telemetering egg for use in incubation and nesting studies. *J. Wildlife Manage.* 38(1):142-148.

Weeden, J. S. 1966. Diurnal rhythm of attentiveness of incubating female Tree Sparrows at a northern latitude. *Auk* 83(3):368-388.